Surface Atmosphere Radiation Budget (SARB) working group update

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SARB working group

- Produces TOA and surface shortwave, longwave and window irradiances, as well as irradiances at 70, 200, and 500 hPa using radiative transfer models.
- The SARB working group contribution to CERES products
  - CRS Instantaneous CERES footprint base, Level 2
  - FSW Gridded instantaneous fluxes
  - CER_SYN1deg-3Hour, CER_SYN1deg-M3Hour, CER_SYN1deg-Month (produced with TISA working group)
  - Surface EBAF (produced with TISA and inversion working groups) Level 3B product, TOA irradiances match with TOA EBAF
  - CRS1deg-Month (Level 3 product, non-GEO surface, proposed)

Outline of this presentation

- Status of EBAF-surface product (details will be presented by F. Rose in this meeting)
- Proposed Edition 4 SYN and CRS changes
- MATCH (aerosol transport model, will be presented by D. Fillmore in this meeting)
- Ed4 surface albedo history map
- 3D radiative transfer using CCCM data (S. Sun-Mack's talk for CCCM data)

Surface radiation budget

- Global annual surface net irradiance balances with the sum of latent and sensible heat fluxes and ocean heating
- Understanding the change of the atmospheric energy budget is a key element in understanding cloud feedback (Wielicki et al. 1995; Stephens 2005).
- The change of the atmospheric energy budget is the driver of global mean hydrological cycle change (Stephens 2005; Mitchell et al 1987; Allen and Ingram 2002; Stephens and Ellis 2008).

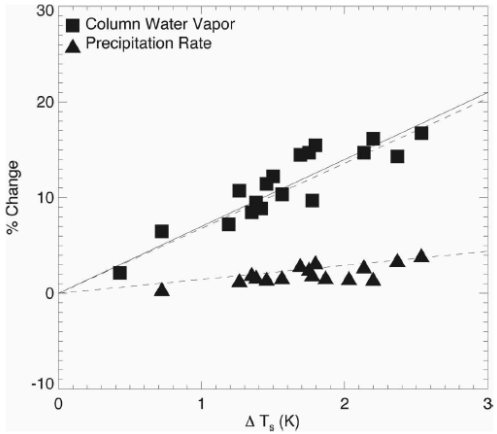


FIG. 3. The relative changes in column water vapor amount and precipitation rate, expressed as percentage changes, as functions of global temperature change derived from the AR4 models. The

Stephens and Ellis (J. Climate 2008)

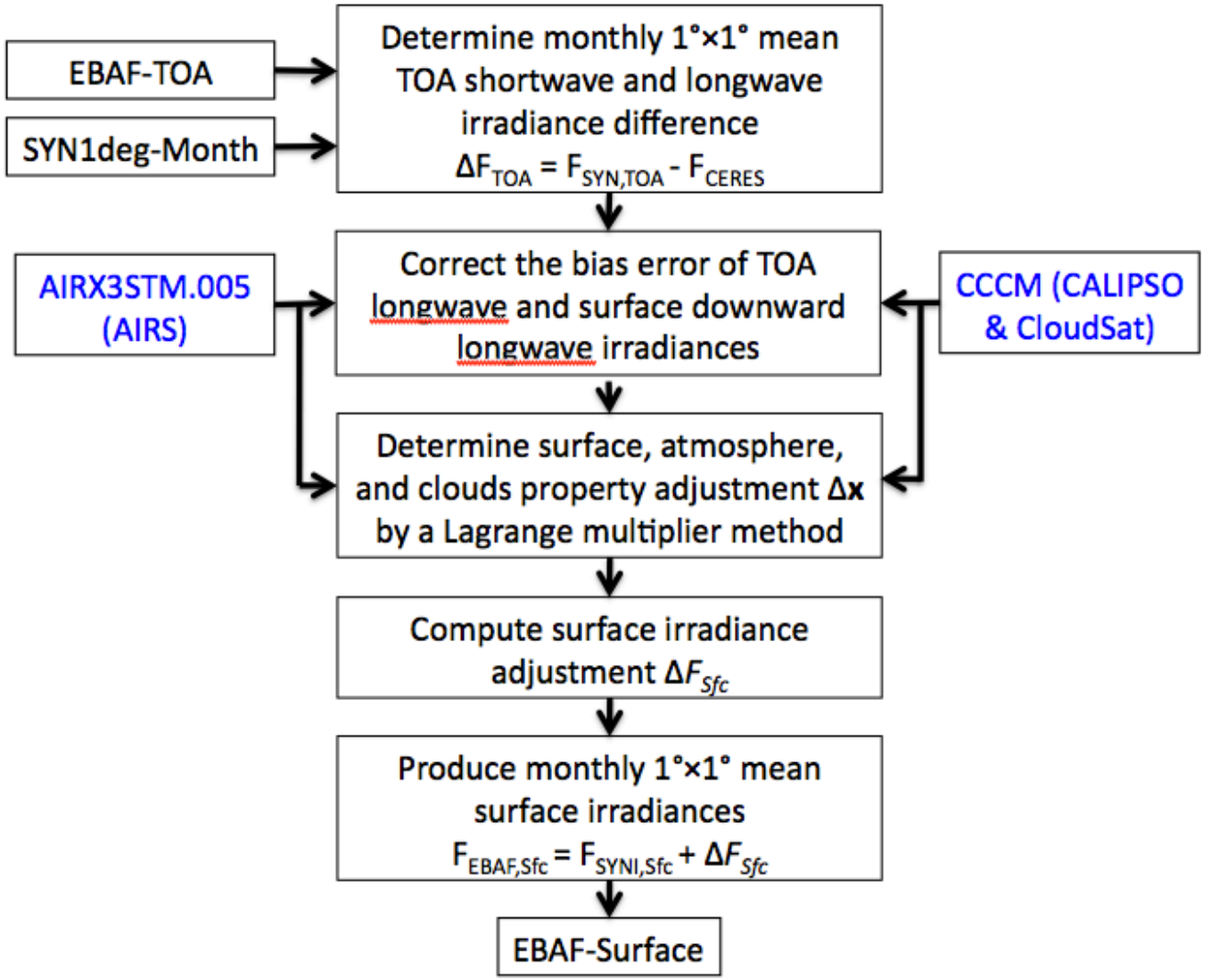
EBAF-surface

- Surface irradiances produced by constraining TOA irradiance by CERES observations (i.e. computed TOA irradiances agree with CERES-derived irradiances).
- Based on CERES EBAF-TOA (consistent with ocean heating) and SYN1-deg-Month (MODIS + GEO merged clouds)
- Ten years (from March 2000 through Feb. 2010) of EBAF-surface (Ed2.6r) data are generated and available from http://ceres.larc.nasa.gov/order_data.php and through Obs4MIPS.
- Correction of MODIS and GEO derived cloud properties by CALIPSO and CloudSat derived cloud properties
- Correction of GEOS-4 and 5 temperature and humidity by AIRS derived temperature and humidity profiles

Objective of EBAF-surface product

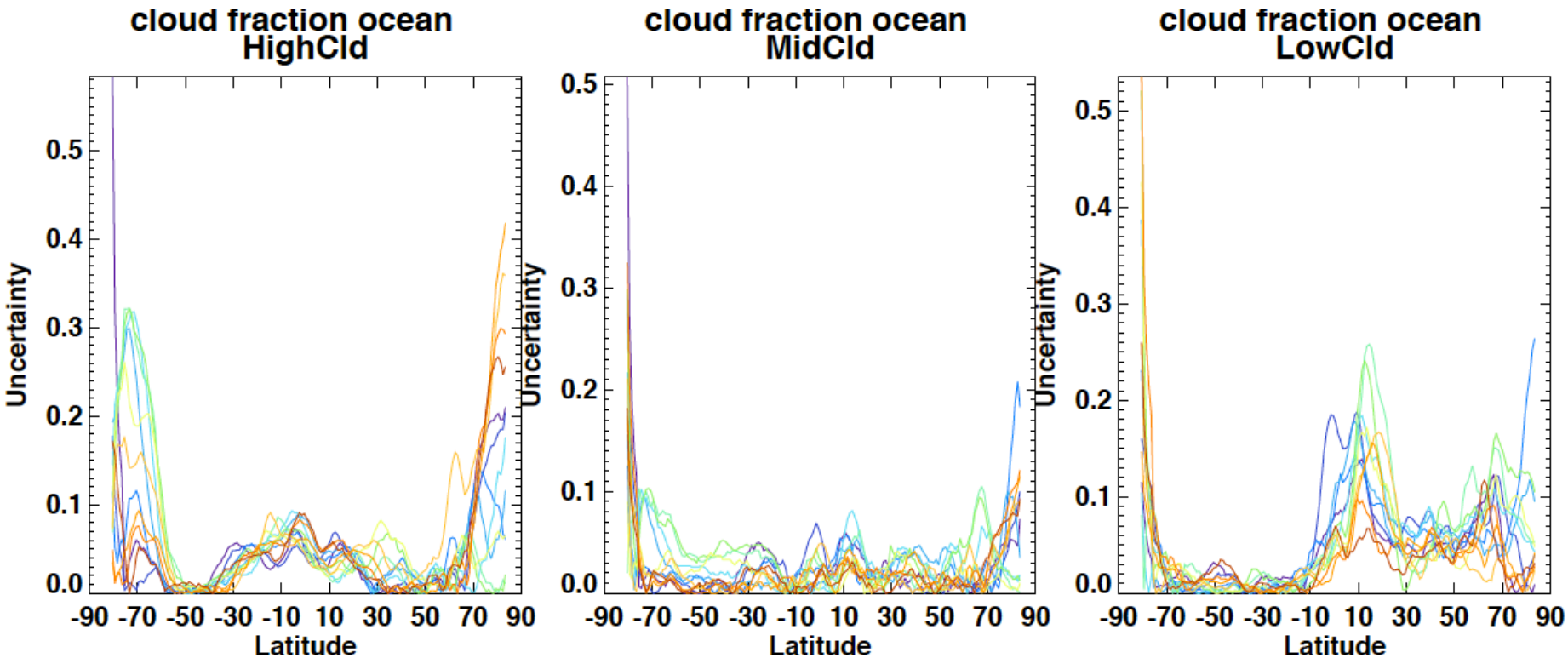
- To provide surface irradiances that are produced with constraints by TOA CERES observations (i.e. surface irradiances are consistent with TOA EBAF within a framework of 1D radiative transfer theory).
- Adjust surface irradiances within their uncertainties

EBAF-surface production flow diagram



Kato et al. 2012 *J. climate* in press

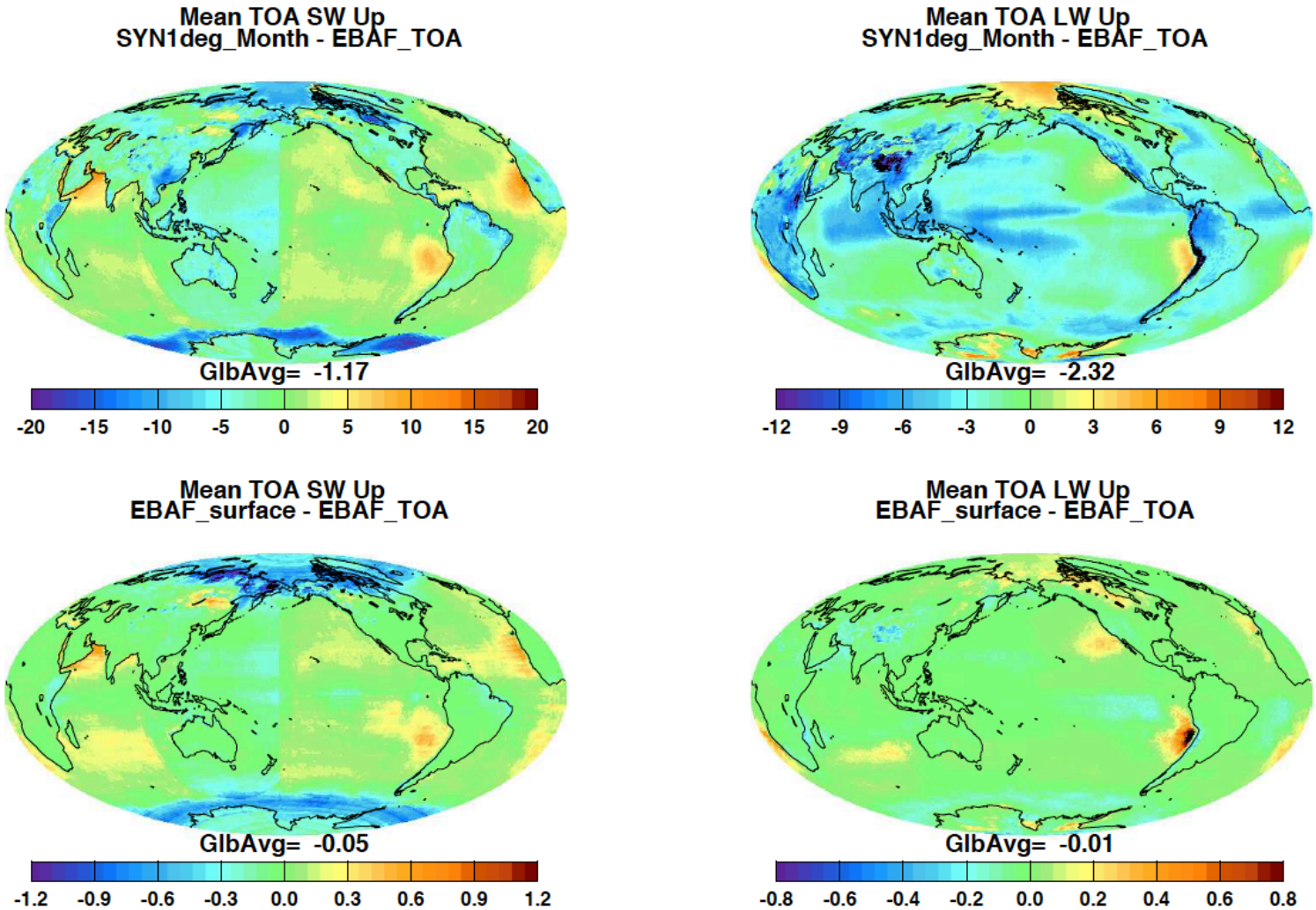
Cloud fraction uncertainty



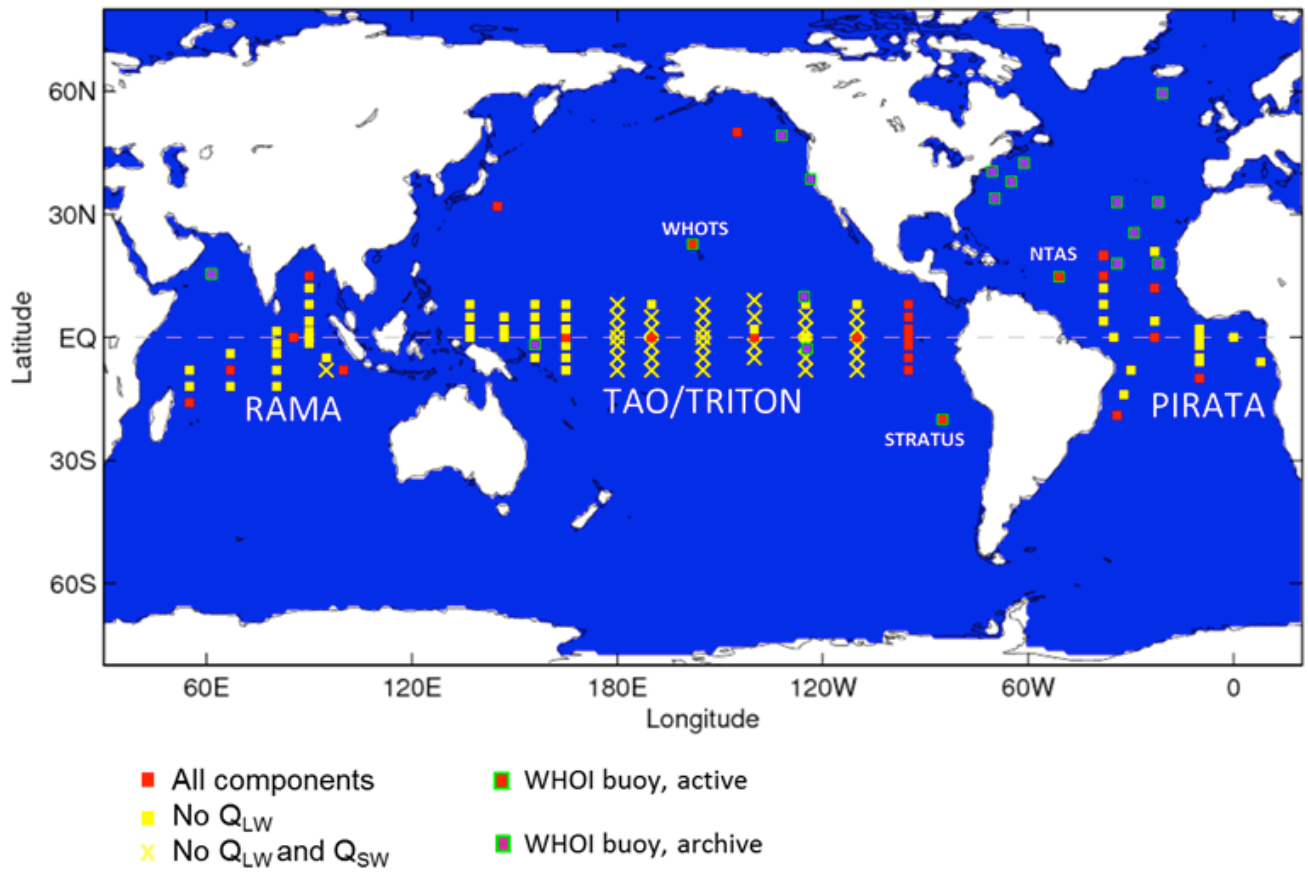
Use the cloud fraction derived from MODIS and CALIPSO-CloudSat as uncertainty.

Cloud and atmospheric properties with larger uncertainty are adjusted more than those with smaller uncertainty

TOA adjustments

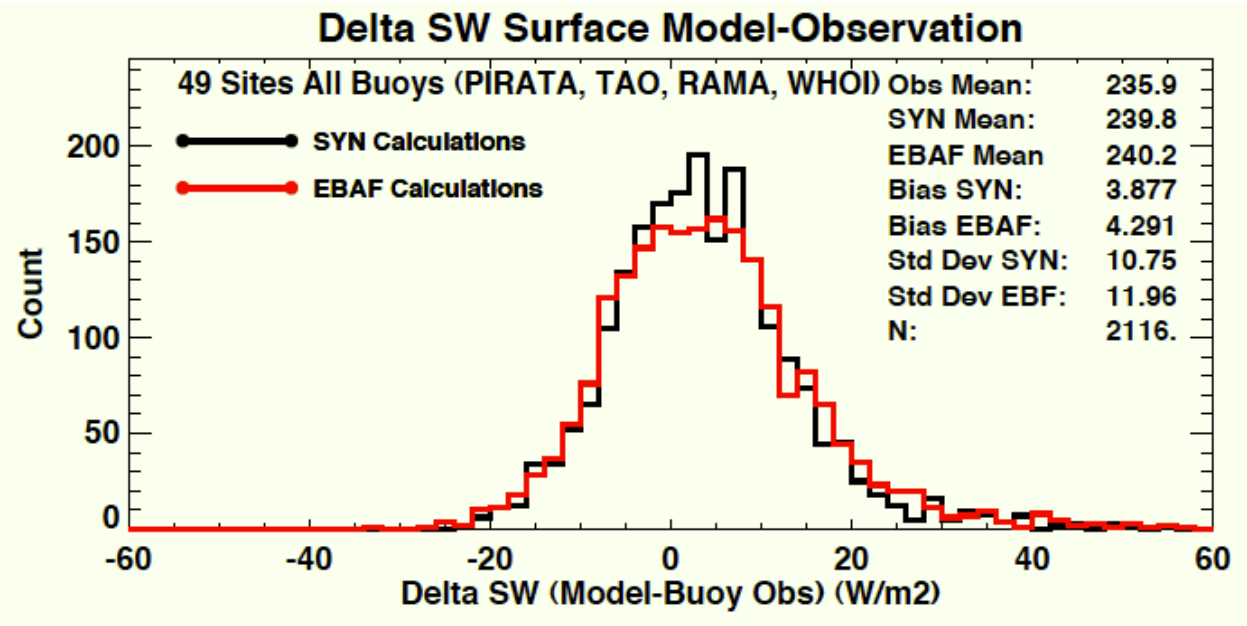


Evaluation with surface observations (Ocean)

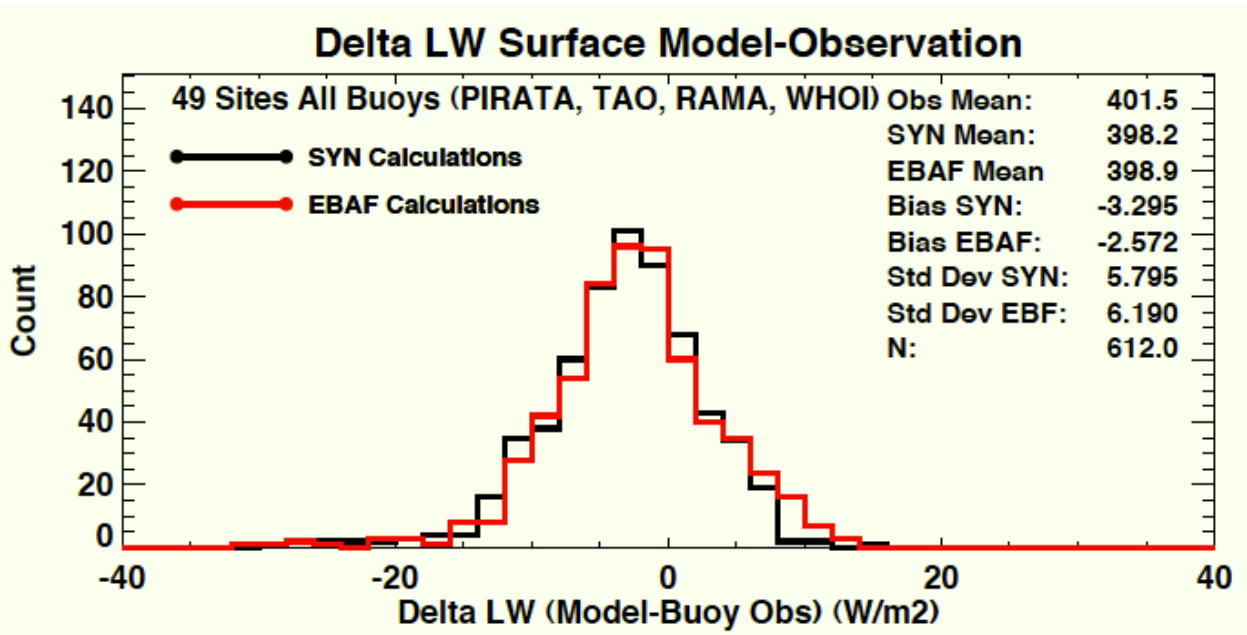


Use 71 buoys for shortwave comparison
Use 23 buoys for longwave comparison

Evaluation with surface observations (Ocean)

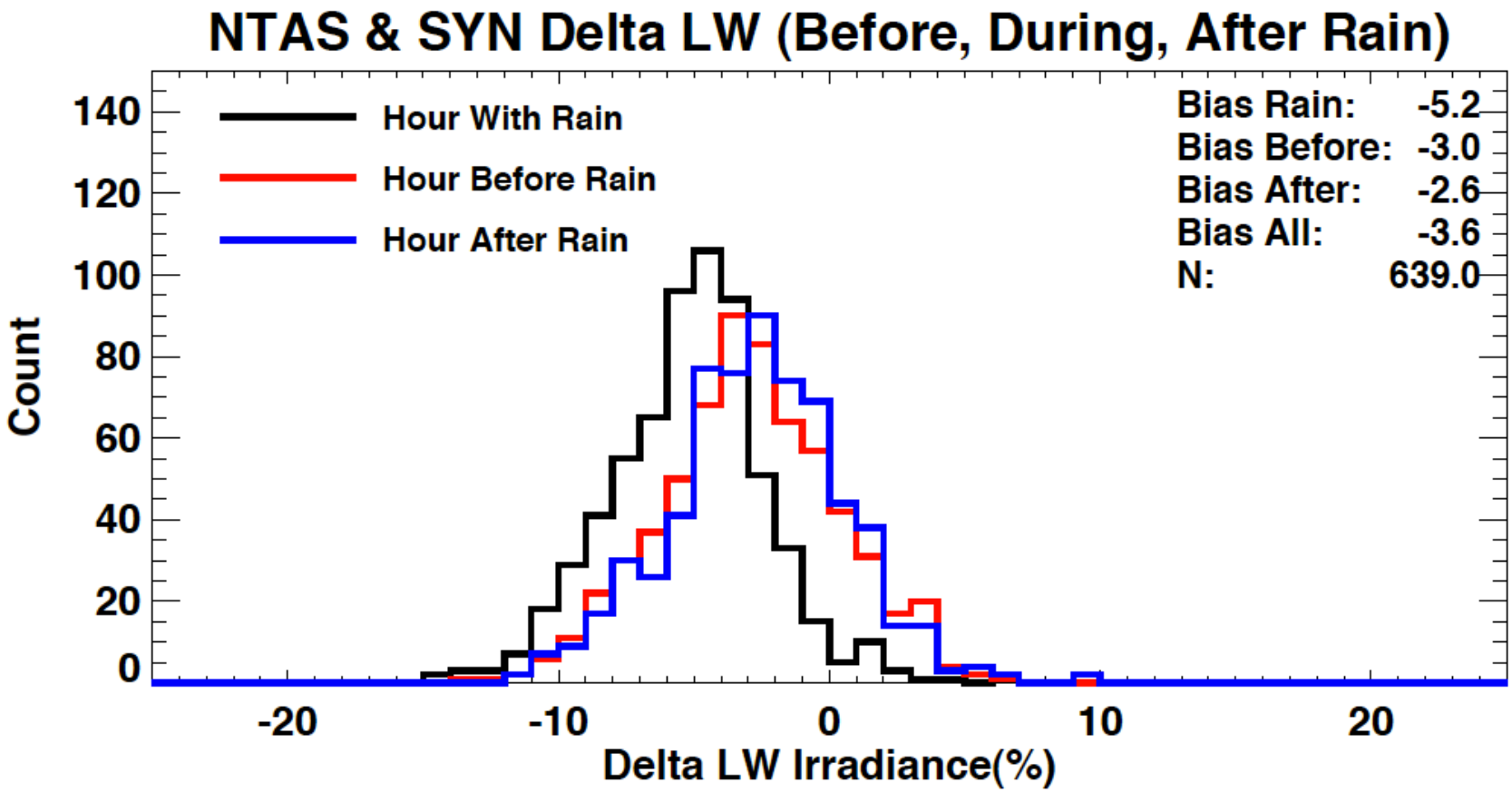


Monthly mean
Comparison
Result depends on
how bad surface
observations are screened

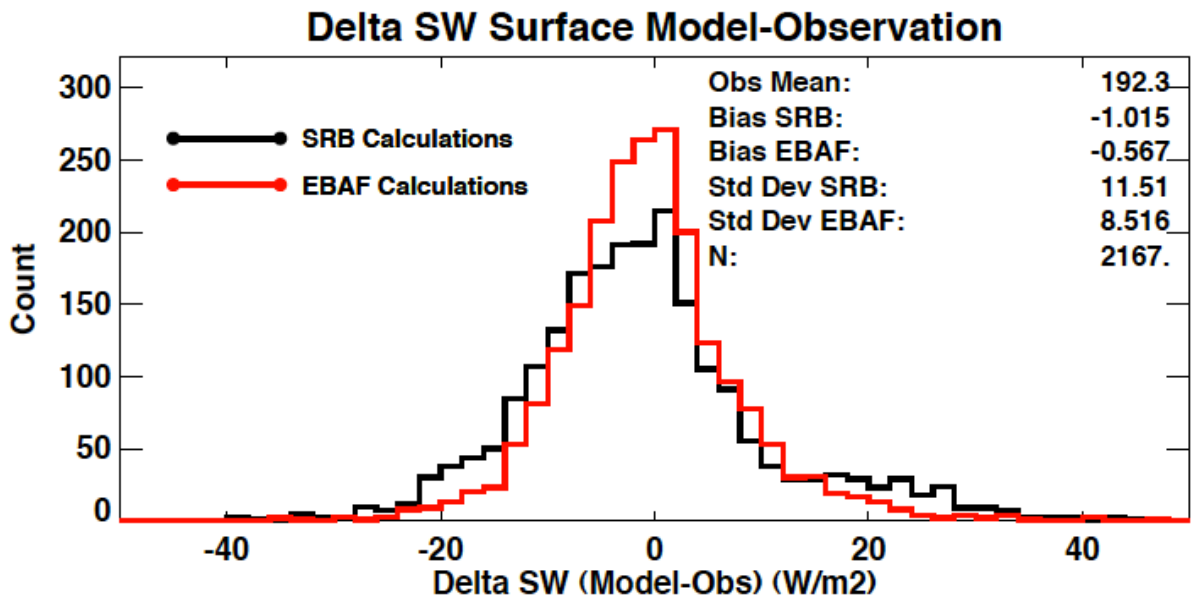


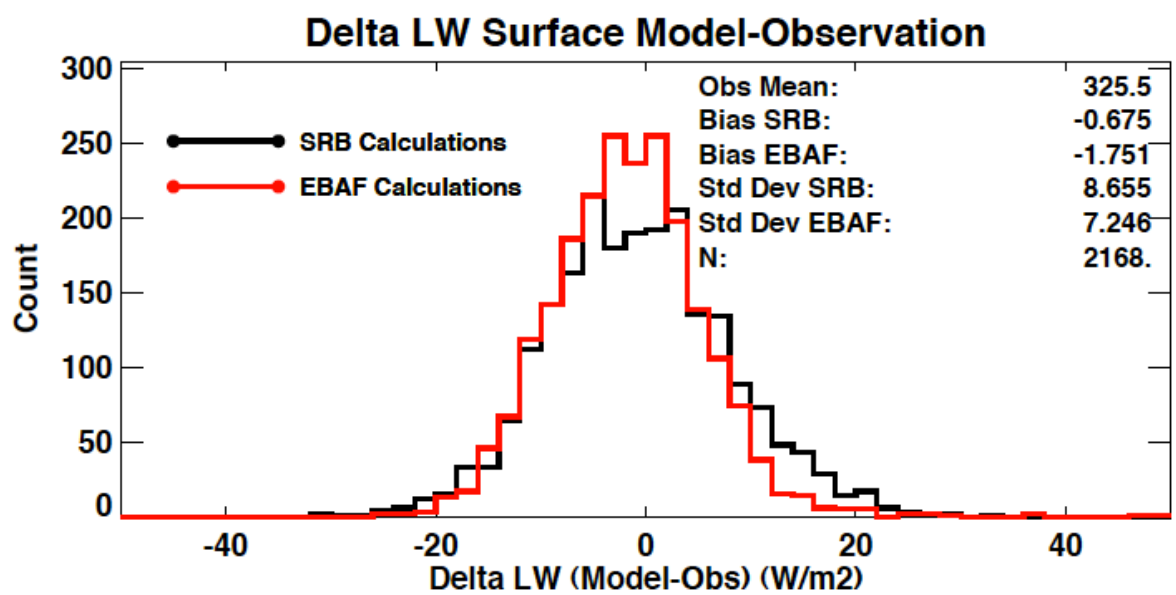
Measurement uncertainty
in
Daily or annual mean
Downward shortwave
5 to 6 Wm^{-2}
Downward longwave
4 Wm^{-2}
(Colbo and Weller 2009)

Downward longwave irradiance depending on precipitation



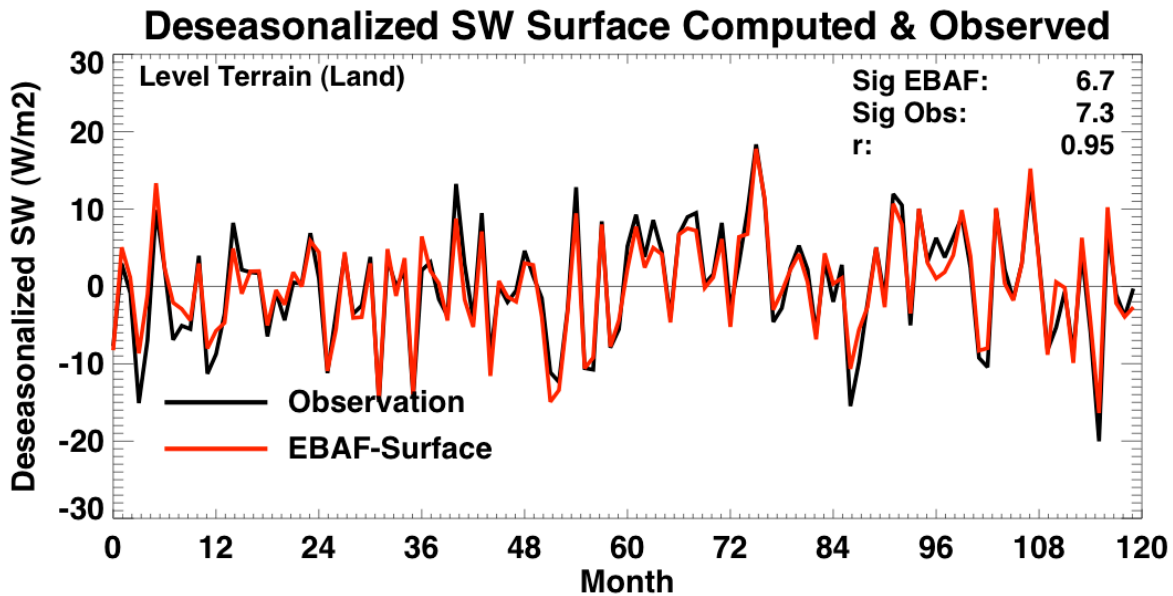
Evaluation with surface observations (Land)

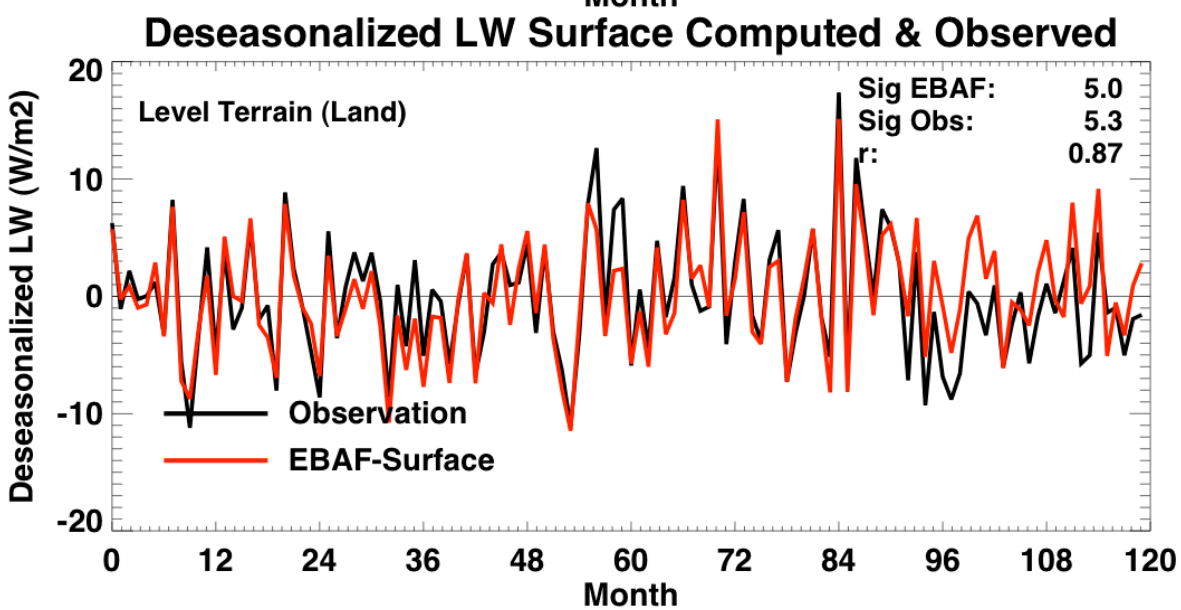




Evaluation with surface observations (land)

24 land surface sites



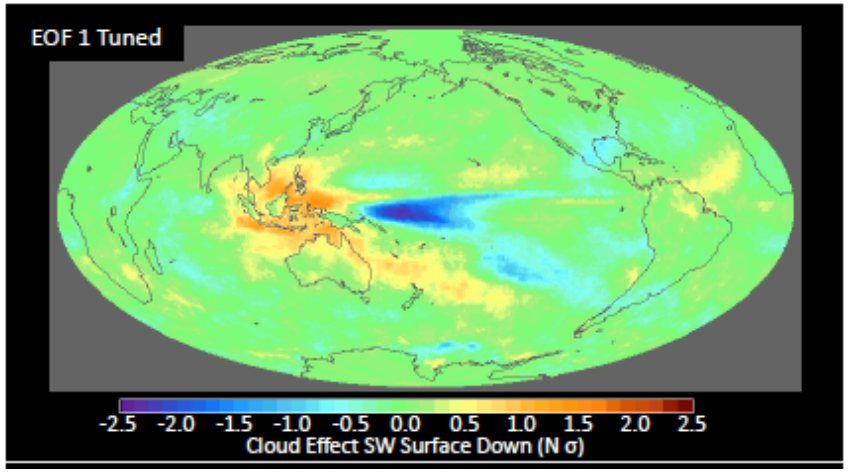


Monthly mean bias[1] (RMS difference) between computed and observed surface irradiances based on 10 years of data (March 2000 – Feb 2010)

	SYN1deg-Month	EBAF-Surface	SRB	Flashflux
Land[2]				
Shortwave down	0.3 (7.6)	-1.7 (7.8)	-3.4 (9.6)	-4.6 (18.9)[4]
Longwave down	-4.2 (8.6)	-1.0 (7.6)	-0.6 (8.9)	1.0 (7.5)[4]
Ocean[3]				
Shortwave down	5.4 (13.4)	4.7 (13.3)	11.4 (17.7)	14.6 (19.1)
Longwave down	-3.3 (7.1)	-2.5 (7.1)	-1.2 (6.4)	-2.0 (7.6)

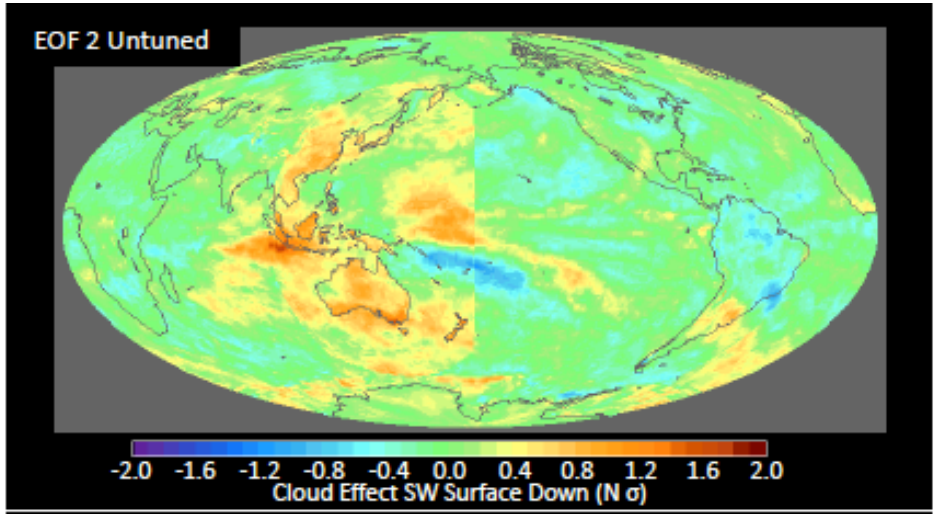
[1] Computed minus observed.
[2] Observations at 24 sites are used.
[3] Observations at 23 buoys for longwave (4 WHOI buoys, 2 RAMA buoys (McPhaden et al. 2009), 11 TRITON/TAO buoys (McPhaden et al. 1998), 4 PIRATA buoys (Bourles et al. 2008), and KEO+PAPA from PMEL)
and 71 buoys for shortwave
(4 WHOI buoys, 17 PIRATA, 14 RAMA, 34 TRITON/TAO, and KEO+PAPA from PMEL) are used.
[4] Only 2009 data are used.

EOF analysis of SW surface cloud effect

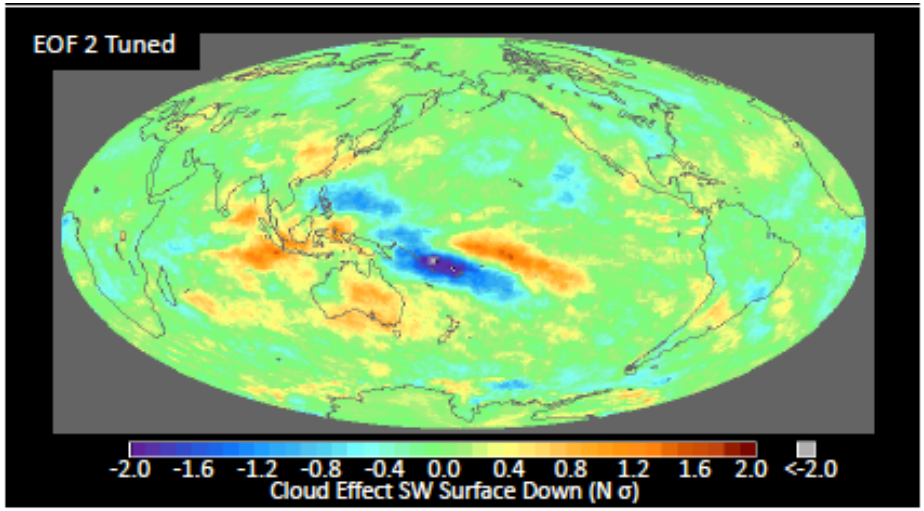


First eigenvectors computed with SYN1deg-Month and EBAF-surface agrees very well but the second Eigenvectors differ

SYN1deg-Month



EBAF-surface



Surface irradiance uncertainty in Wm^{-2} (1σ, k = 1)

		Mean value	Monthly gridded	Monthly zonal	Monthly global	Annual global
Downward longwave	Ocean+Land	345	14	11	7	7
Upward longwave	Ocean+Land	398	15	8	3	3
Downward shortwave	Ocean+Land	192	10	8	6	4
Upward shortwave	Ocean+Land	23	11	3	3	3

Estimated uncertainty of the global annual mean net surface irradiance is 12 Wm^{-2}

Kato et al. (2012)
Surv. Geophys., Doi 10.1007/s10712-012-9179-x.

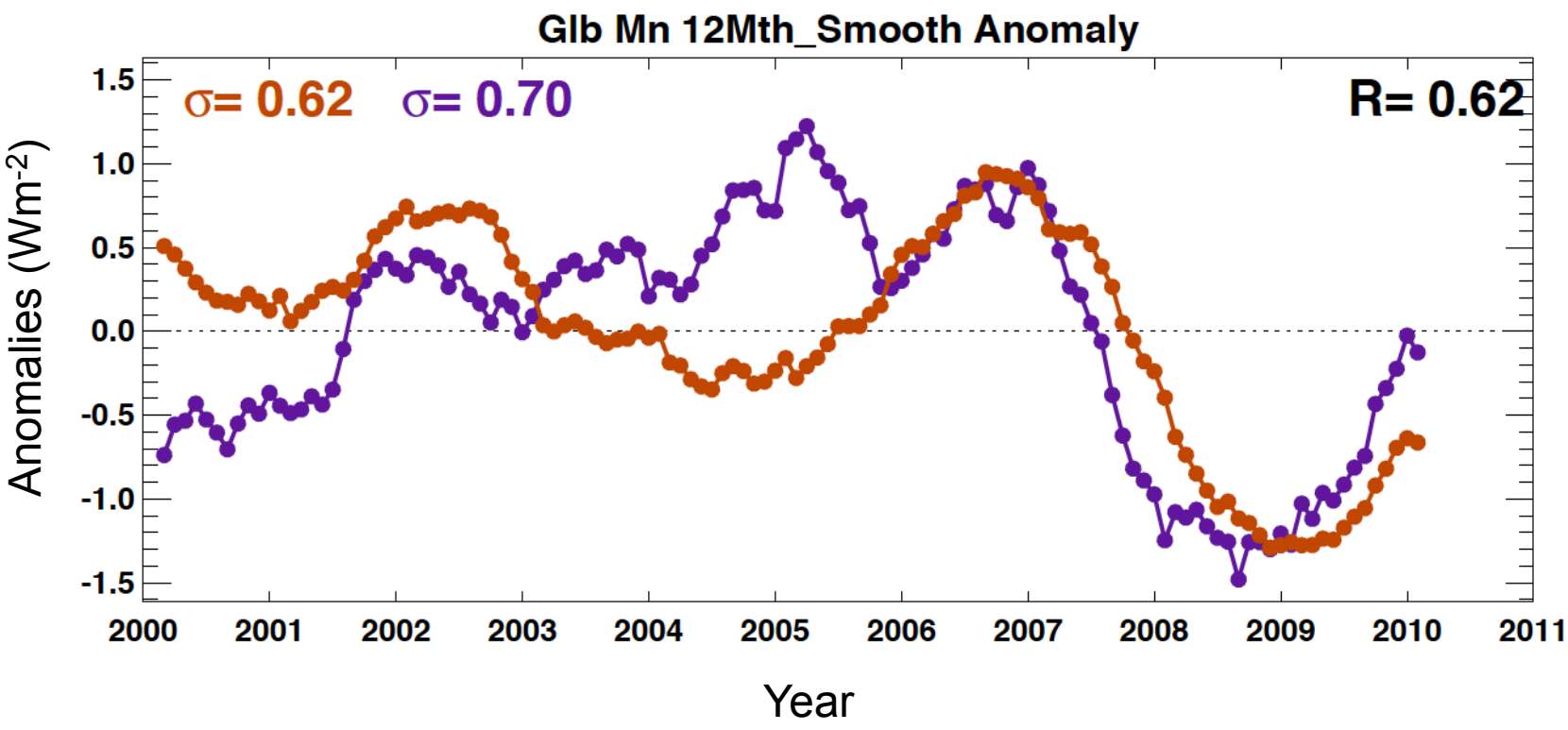
Global annual surface radiation budget

Irradiance component	Ed 2 SYN1deg-Month	Surface EBAF Ed2.6r
LW down (all-sky)	342	344±7
LW up (all-sky)	398	398±3
SW down (all-sky)	187	187±4
SW up (all-sky)	23	24±3
Net (all-sky)	108	108±12
LW down (clear-sky)	314	314
LW up (clear-sky)	397	398
SW down (clear-sky)	242	243
SW up (clear-sky)	29	30
Net (clear-sky)	131	130

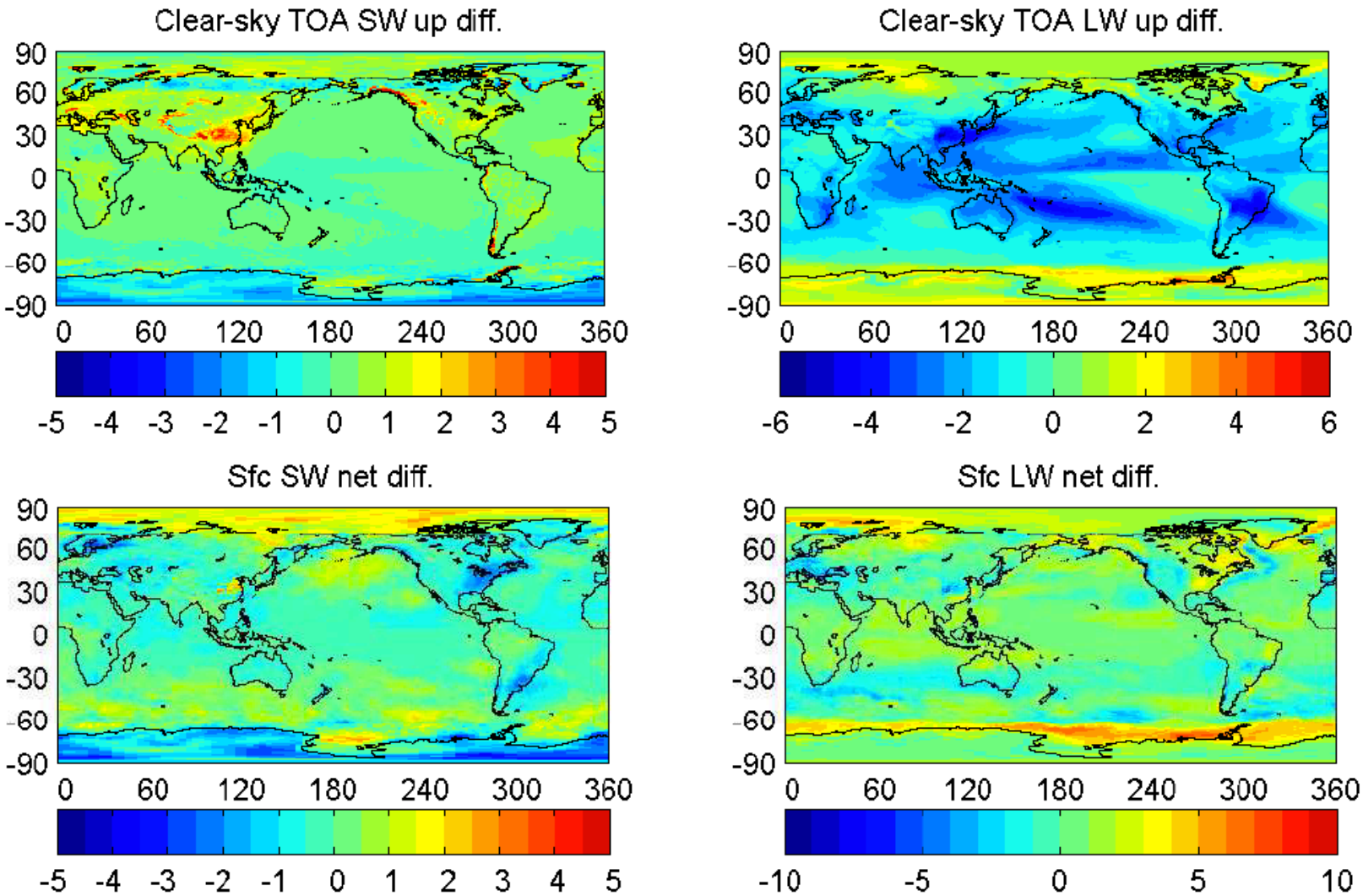
Latent heat flux = 88 Wm^{-2} and sensible heat flux = 21 Wm^{-2} (Stephens et al. 2012)

Comparison with GPCP

Red: EBAF-surface + ERA-interim sensible heat flux
Blue: GPCP



Clear-sky irradiances



clear-sky fluxes are clear-sky fraction-weighted fluxes
instead of fluxes computed by removing clouds

Clear-sky global mean difference

Global clear-sky irradiance difference in Wm^{-2}
(cloud removed minus clear-sky fraction weighted irradiances)

		Monthly		Annual
		Mean	RMS	RMS
TOA	SW up	0.24	0.29	0.25
	LW up	-1.25	1.26	1.25
Surface	SW down	-0.88	0.90	0.88
	SW up	-0.04	0.10	0.05
	LW down	1.63	1.67	1.63
	LW up	0.42	0.53	0.42

GEOS-4 and other problems

- The source of temperature and humidity profiles for surface flux calculations changes from GEOS-4 to GEOS-5 starting in November 2007. When deseasonalized anomalies are calculated separately for land and ocean, the time series of deseasonalized surface fluxes shows a discontinuity between October 2007 and November 2007.
- Because of the near surface temperature error in GEOS-4 over tropics in 2004, deseasonalized anomalies of downward longwave irradiance in 2004 show larger anomalies, when 10-year means are used to compute deseasonalized anomalies (F. Rose presentation for details of the correction of GROS-4 problem).
- 1°×1° grids are shifted eastward by 1 degree
- Please read "EBAF-surface Data Quality Summary (DQS) before start using data.

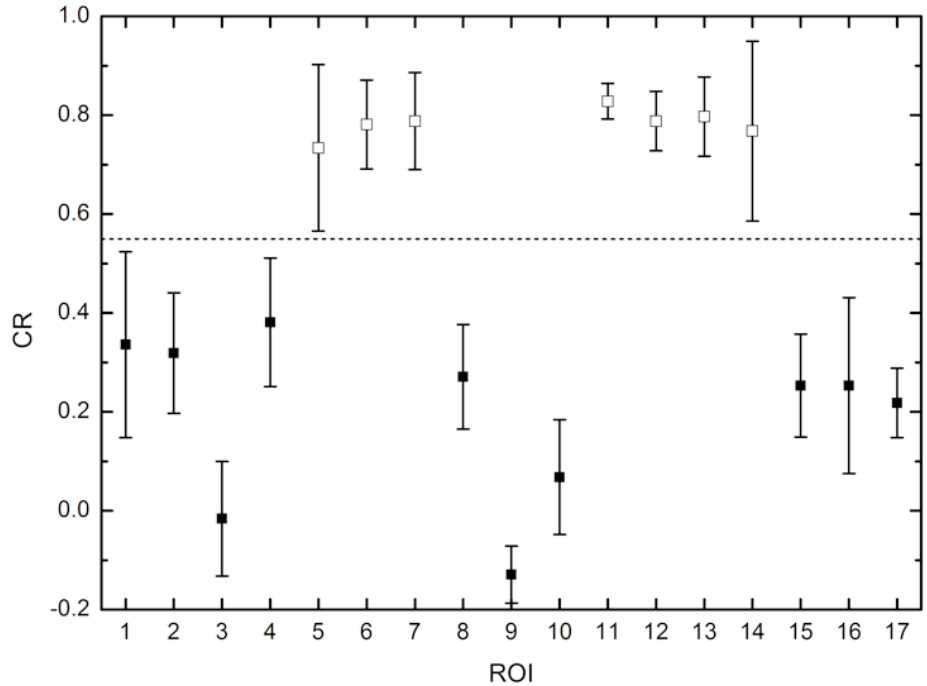
SYNI Ed4 plan

- Cloud overlap
- Hourly MATCH
- Ed4 surface history map
- Ed4 Fu-Liou code (need a significant revision)
- Aerosol radiative effect products (proposed)
- Entropy computations (proposed)

Ed4 surface albedo history map algorithm

1. **Narrowband to broadband coefficients**
   - Identify cloud free footprints
   - Cloud free FOVs with 100% IGBP coverage of certain types are selected
   - Sort selected clear-sky elected FOVs by IGBP type (all types except cryosphere (15, 19, 20), ocean (17), and urban (13)), and by SZA (9 bins of 10 deg), VZA (7 bins of 10 deg), RelAZ (9 bins of 20 deg,)
   - CERES SW radiances are fitted against 7 MODIS radiances available in Ed 4 records (0.469, 0.555, 0.645, 0.858, 1.240, 1.640, and 3.792 microns) in each bin providing regression coefficients and coefficient of determination, R^2.
2. **Narrowband to broadband conversion**
   - Cloud fraction between 10% and 99.9% are selected if single IGBP type covers 100%
   - the selected FOVs are binned in the same way as for 100% clear, see I.3;
   - Apply narrowbwnd to broadband conversion to MODIS radiances averaged over cloud free area within a CERES footprint
3. **TOA irradiance to surface irradiance**
   - ADMs are applied to the derived radiances;
   - SW TOA fluxes derived from MODIS are passed to the standard surface albedo algorithm.

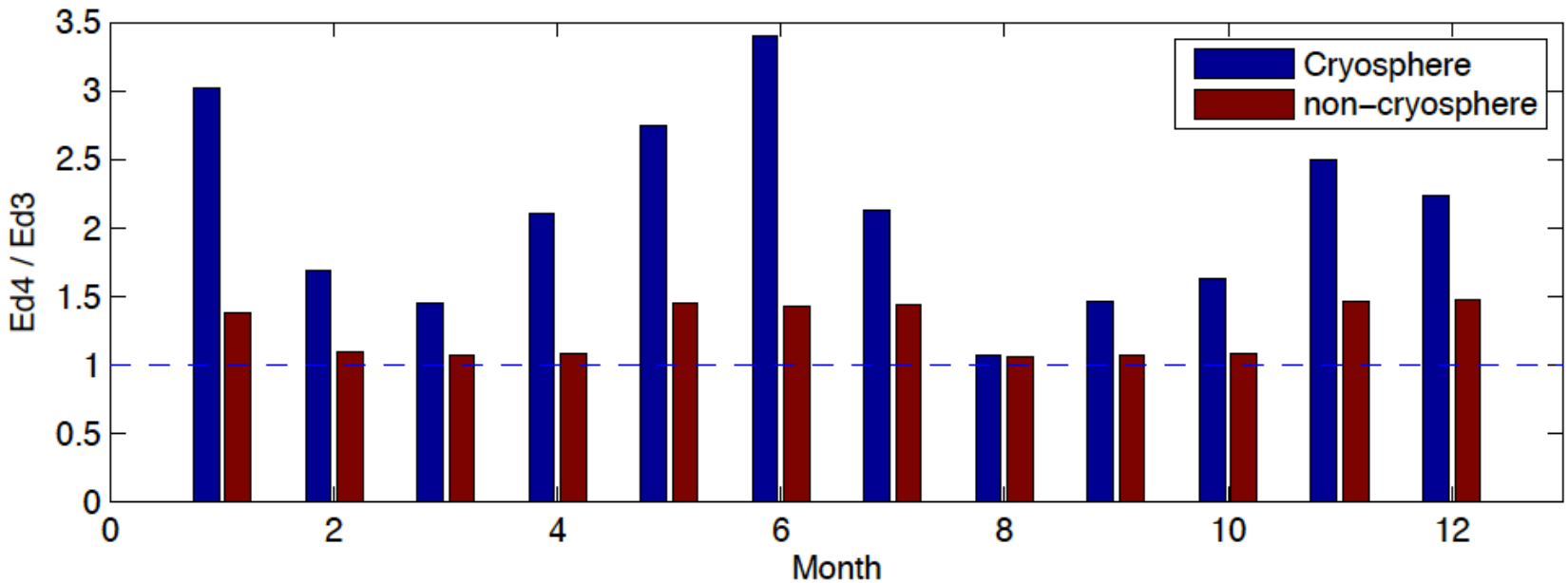
Clear-sky identification over cryosphere



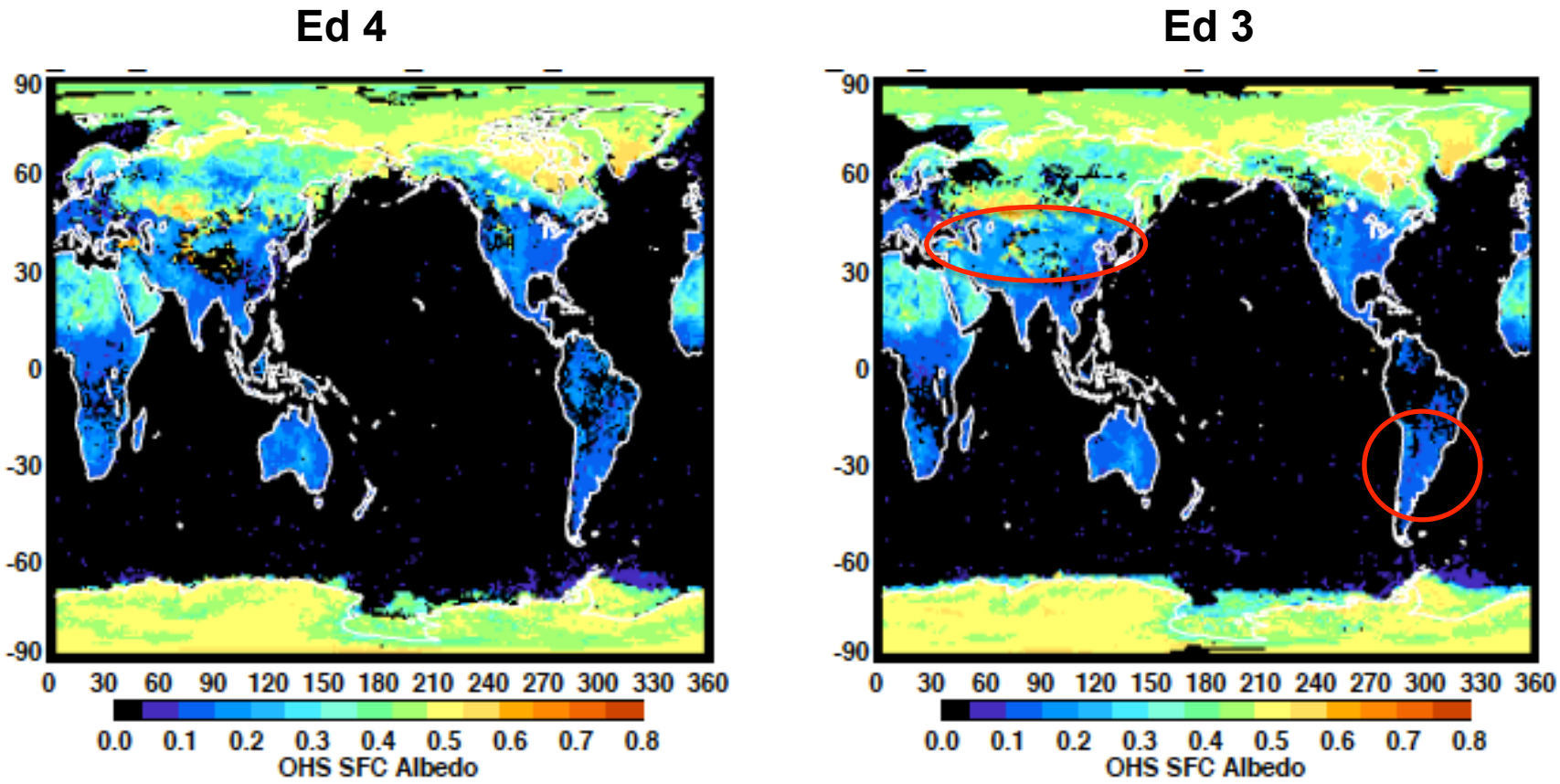
$$CR = NDSI_c + NDVI + (TR - 1) + (BTR - 1)$$

NDSI = [r(0.6) – r(1.6)] /[r(0.6)+r(1.6)]
NDVI = [r(0.86) – r(0.6)] /[r(0.86)+r(0.6)]
TR = T(11) / Tsfc
BTR = T(11)/ T(3.8)

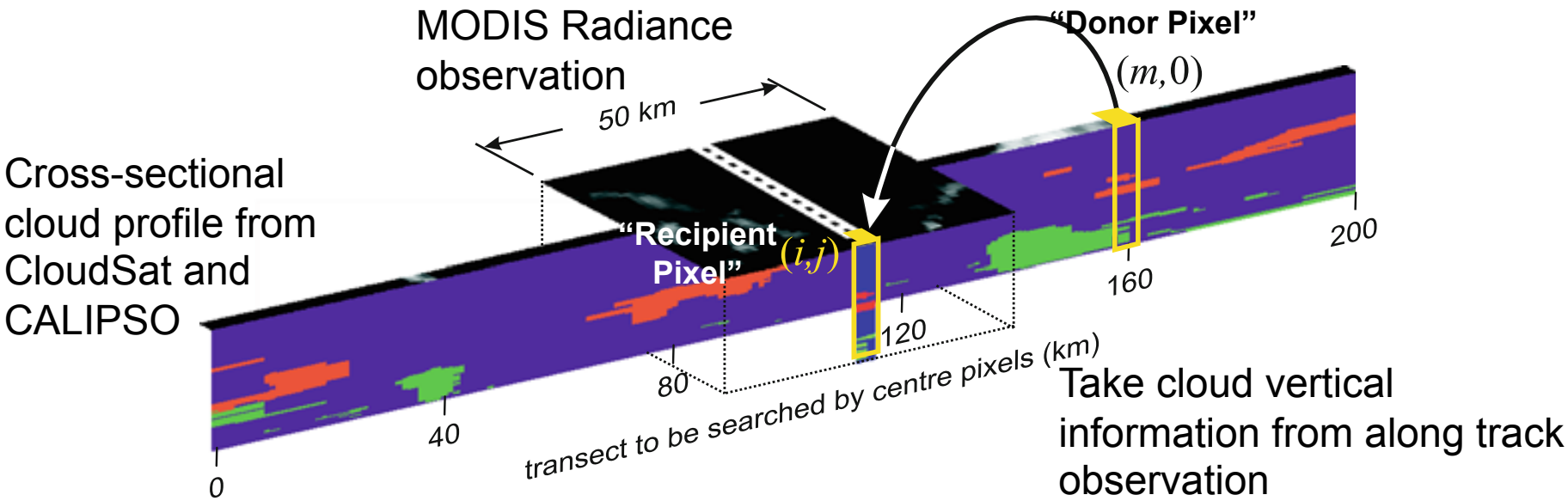
ED4 versus ed3 sampling



Improvements by ed4 surface history map algorithm



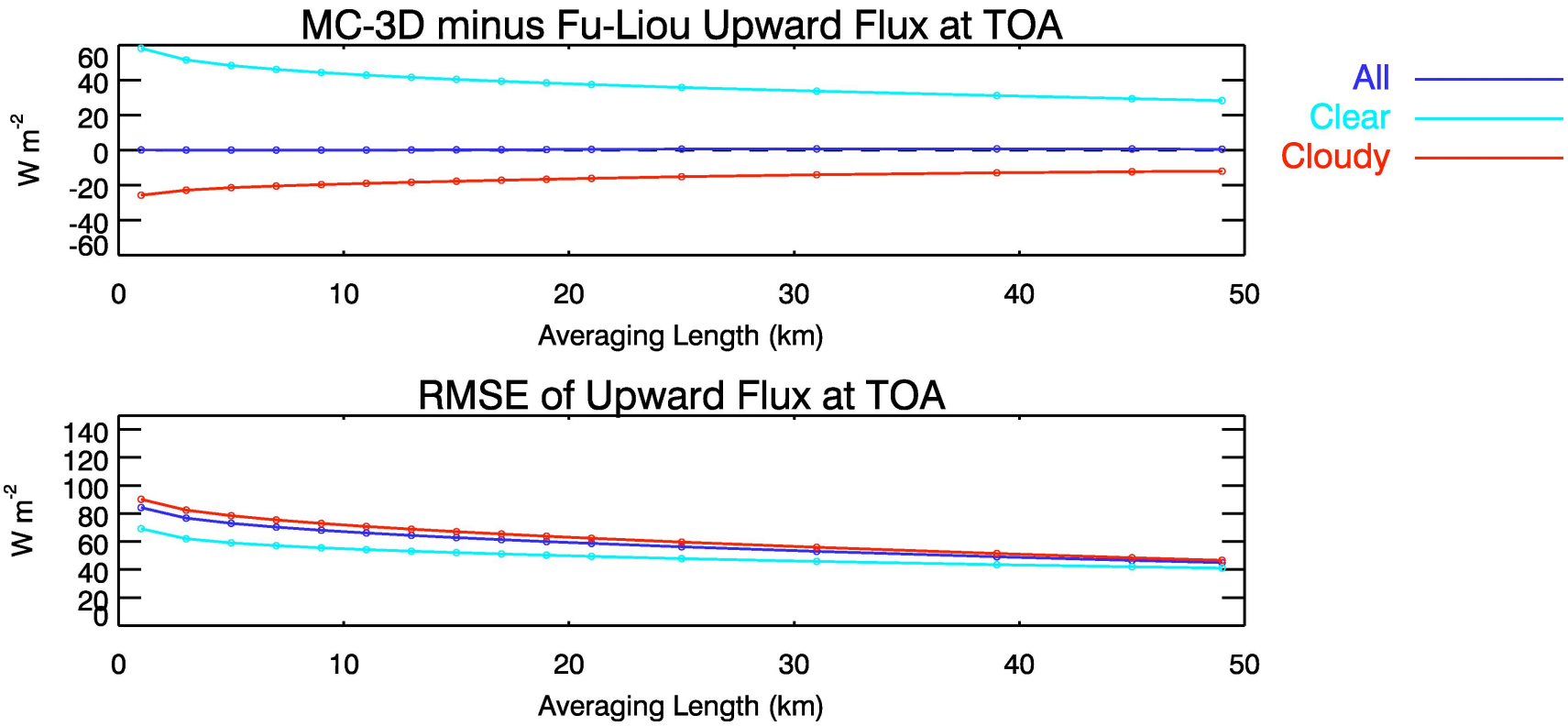
3-D Cloud Construction Algorithm from 2-D Cloud Observation (Barker et al., 2011)



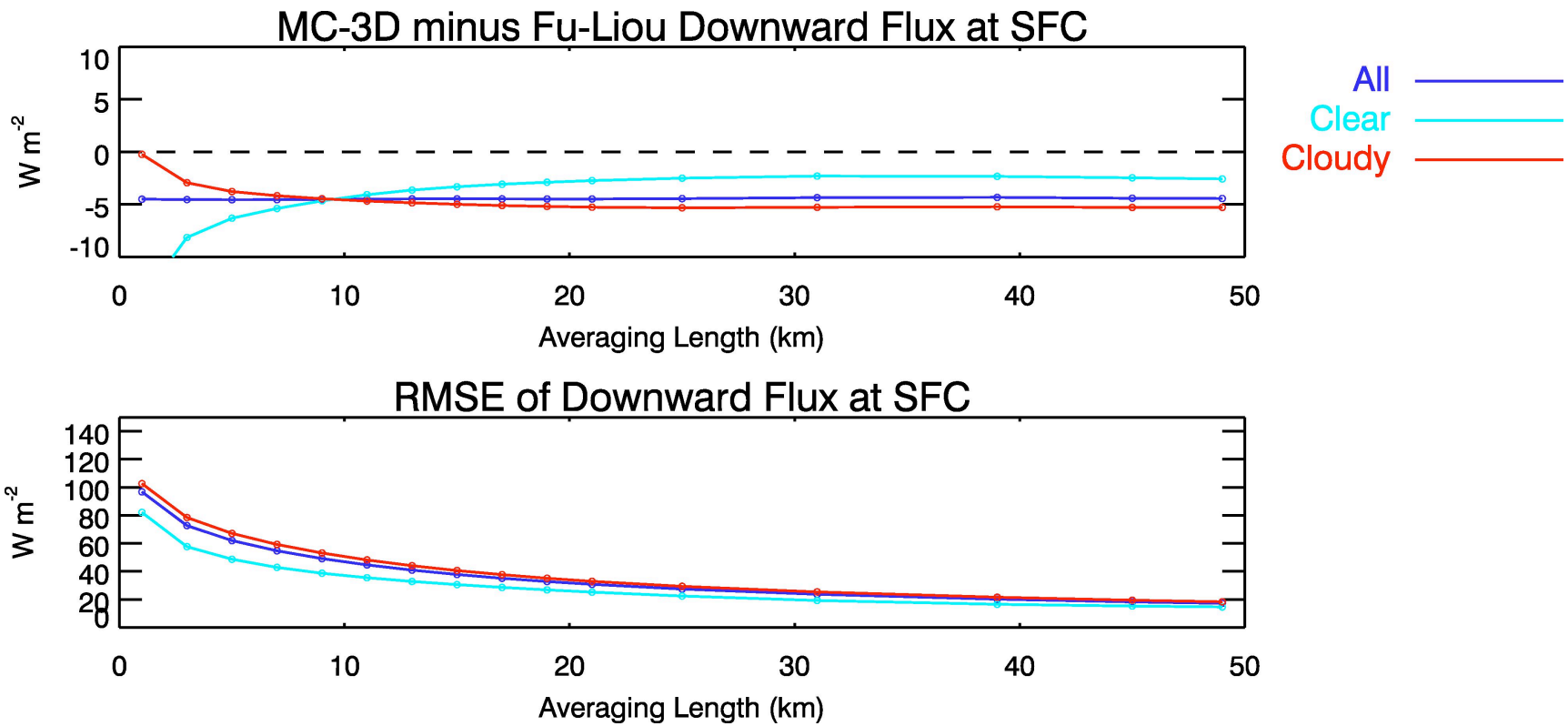
Reference

Barker, H. W., M. P. Jerg, T. Wehr, S. Kato, D. P. Donovan en R. J. Hogan, 2011: A 3D cloud-construction algorithm for the EarthCARE satellite mission. *Quart. J. Royal Meteor. Soc.*, **137,** 1042-1058, doi:10.1002/qj.824

3D Monte Carlo minus Fu-Liou Upward Flux at TOA (Preliminary)



3D Monte Carlo minus Fu-Liou Downward Flux at SFC (preliminary)



Publications

- Kato, S., F. G. Rose, S. Sun-Mack, W. F. Miller, Y. Chen, D. A. Rutan, G. L. Stephens, N. G. Loeb, P. Minnis, B. A. Wielicki, D. M. Winker, T. P. Charlock, P. W. Stackhouse, K.-M. Xu, and W. Collins, 2011, Improvements of top-of-atmosphere and surface irradiance computations with CALIPSO, CloudSat, and MODIS derived cloud and aerosol properties, *J. Geophys. Res*., VOL 116, D19209, doi:10.1029/2011JD16050.
- Kato, S., N. G. Loeb, D. A. Rutan, F. G. Rose, S. Sun-Mack, W. F. Miller, and Y. Chen, 2012; Uncertainty estimate of surface irradiances computed with MODIS-, CALIPSO-, and CloudSat-derived cloud and aerosol properties, *Surv. Geophys*., Doi 10.1007/s10712-012-9179-x.
- Rose, F., D. A. Rutan, T. P. Charlock, G. L. Smith, and S. Kato, 2012; An algorithm for the constraining of radiative transfer calculations to CERES observed broadband top of atmosphere irradiance, submitted to *J. Ocean. Atmos. Technol.*
- Radkevich, A., K. Khlopenkov, D. Rutan, S. Kato, 2012, A Supplementary Clear-Sky Snow and Ice Recognition Technique for CERES Level 2 Products, Submitted to *J. Atmos. Oceanic Technol.*
- Kato, S., N. G. Loeb, F. G. Rose, D. R. Doelling, D. A. Rutan, T. E. Caldwell, L. Yu, and R. Weller, 2012, Surface irradiances consistent with CERES-derived top-of-atmosphere shortwave and longwave irradiances

- Ed2 CRS DPC/collection guide (working in progress)

Summary

- 10 years (from March 2000 through Feb. 2010) of EBAF-surface data are produced and available from (http://ceres.larc.nasa.gov/order_data.php).
- The first revision of EBAF-surface will be within 6 months
- Ed4 SYN algorithms are planned and under development. Ed4 SYN algorithm delivery is due Feb./March 2014. CRS ed4 code is due summer 2014.

Surface adjustments